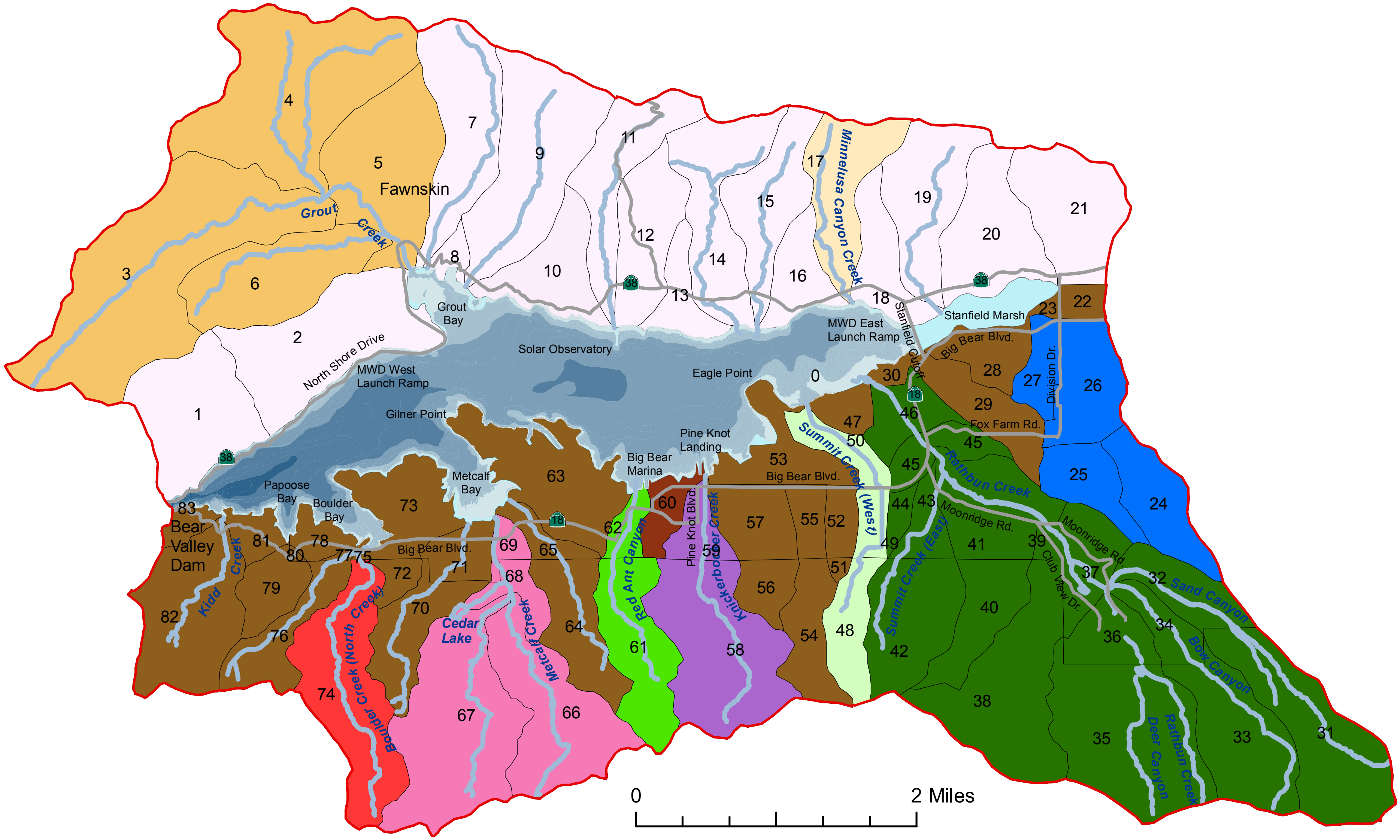
A total of 4,466 acres are currently in the City of Big Bear Lake's planning area and are designated for a variety of land uses, including residential, commercial, and industrial. The southern boundary of the City of Big Bear Lake's sphere of influence follows the USFS' boundary (City of Big Bear Lake 1999, LU-3) (see Figure 1-1).

For modeling purposes, the Big Bear Lake watershed was delineated using the watershed boundaries from CalWater v. 2.2 and incorporated the Hydrologic Subarea Boundary (HSA) of Bear Valley (801.71). Further refinement of the watershed boundary was obtained using the USGS 7.5 Minute Quadrangle sheets (Fawnskin, Moonridge, Big Bear Lake, and Big Bear City). The watershed was then further divided into 83 subbasins (Figure 1-7) to permit the greatest flexibility in simulating watershed processes. The subbasins were delineated based on topographic features, stream reaches, and the storm water system Geographical Information System (GIS) files supplied by the City of Big Bear Lake. The Rathbun Creek subwatershed consists of subbasins 31-46 as shown in Figure 1-7.

Utilizing GIS analysis, the areas of various types of land use within the watershed were determined (Table 1-2, Figure 1-8). These land uses were also used for the Hydrological Simulation Program Fortran (HSPF) model development (see Section 4.0). Land use layers were derived from the City of Big Bear Lake's current (2002) zoning map and 1996 aerial photos from the USGS. The following ratios were used to determine the percentage of impervious/pervious area for each land use: forest north (0.5%, 99.5%); forest south (0.5%, 99.5%); resort (5%, 95%); residential (15%, 85%); and high density urban (50%, 50%)[2]. The majority of land use area in the Big Bear Lake watershed is still pervious. The predominant land use in the watershed is forest (62.7%). The resort land use designation includes the ski resorts, parks and golf courses. The historic ski resort, Snow Forest, near Knickerbocker Creek, was also included in the resort land use category. High density urban includes commercial, industrial and multiple family land uses (BBMWD, Hydmet, Inc., and AquAeTer, Inc. 2003).

[2] The nomenclature "Forest North" and "Forest South" refer to the topographic aspect, not to whether the forest is located to the north or south of the lake. Distinctions in topographic aspects were important to the HSPF modeling effort because of the effect of snow accumulation and snowmelt on water resources. North facing slopes accumulate more snow and melt slower than do south facing slopes.



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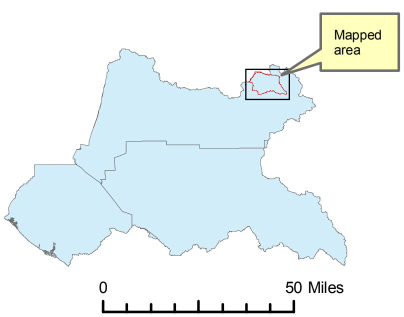
Data Sources:
Tributaries (modified by RWQCB 8) - San Bernardino County, 2004
Watershed boundary, subbasins - Hydmet, Inc., 2003
Lake bathymetry - ReMetrix, Inc., 2000
Major roads - San Bernardino County, 2004



N

Map Features

Subbasins
- Local North
- Grout Creek
- Minnelusa Canyon
- Local South
- Division Creek
- Rathbun Creek
- Summit Creek (West)
- Knickerbocker Creek
- Red Ant Canyon
- Metcalf Creek
- Boulder (North) Creek

Big Bear Lake Tributaries

Big Bear Lake Bathymetry

DEPTH
- 69 - 51 feet
- 50 - 36 feet
- 35 - 21 feet
- 20 - 9 feet
- 8 - 1 feet

Big Bear Lake watershed boundary

Major roads

Figure 1-7.
Big Bear Lake subbasins

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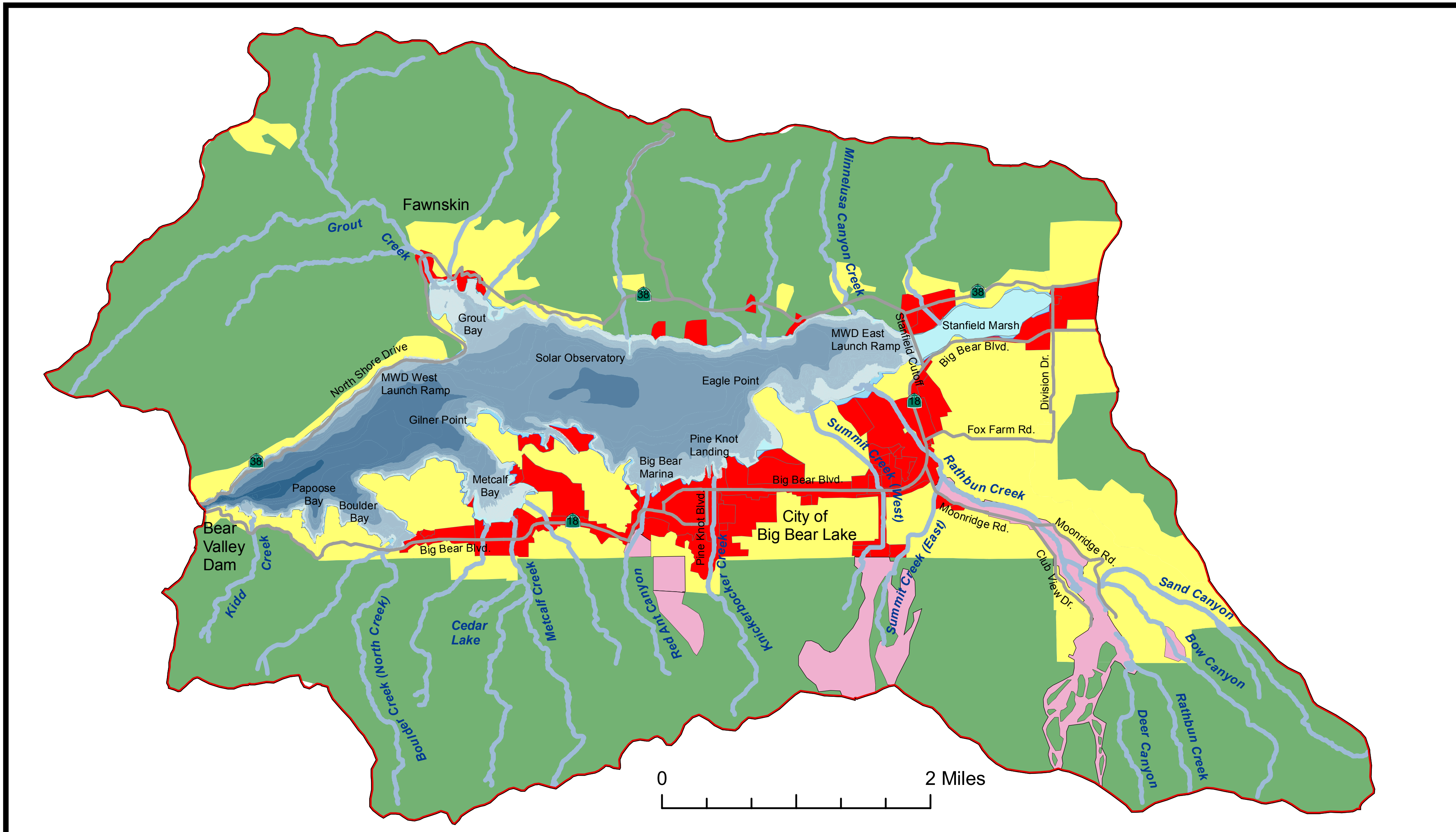
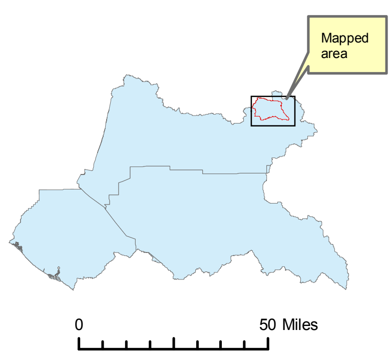
Map contact: Heather Boyd, CA Regional Water Quality Control Board, Santa Ana Region, June 2005



Data Sources:
Tributaries (modified by RWQCB 8) - San Bernardino County, 2004
Watershed boundary, Land use - Hydmet, Inc., 2003
Lake bathymetry - ReMetrix, Inc., 2000
Major roads - San Bernardino County, 2004
City of Big Bear Lake boundary - City of Big Bear Lake, 2002



Map Features

Big Bear Lake Tributaries

Big Bear Lake Bathymetry

DEPTH

- 69 - 51 feet
- 50 - 36 feet
- 35 - 21 feet
- 20 - 9 feet
- 8 - 1 feet

Big Bear Lake watershed boundary

Major roads

Land Use

- Commercial Resort
- Forest
- High Density Urban
- Residential
- Water

Figure 1-8.
Land Use within the
Big Bear Lake watershed

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Map contact: Heather Boyd, CA Regional Water Quality Control Board, Santa Ana Region, June 2005

Table 1-2. Impervious and Pervious land use distribution in the Big Bear Lake watershed

	AREA (acres)			
Major Land Use Type	**Impervious**	**Pervious**	**Total**	**Percentage of Watershed (%)**
Forest North	38	7,595	7,633	32.9
Forest South	35	6,876	6,911	29.8
Resort	35	669	704	3.0
Residential	580	3,287	3,867	16.7
High Density Urban	644	644	1,288	5.5
Big Bear Lake	-	-	2,808	12.1
Total Watershed	1,332	19,071	23,211	100

Note: Forest North and Forest South refer to the aspect, not to whether the forest is located to the north or south of the lake.
Source: Modified from Hydmet, Inc. 2004

Shown in Table 1-3, are the pervious and impervious land use distributions for Rathbun Creek. The percentages of impervious/pervious land use identified for the watershed as a whole were also used for this subwatershed. The predominant land use in the Rathbun Creek subwatershed is forest.

Table 1-3. Impervious and pervious land use distribution in the Rathbun Creek subwatershed

	AREA (acres)			
Major Land Use Type	**Impervious**	**Pervious**	**Total**	**Percentage of Subwatershed (%)**
Rathbun Creek				
Forest North	10	1,991	2,001	49
Forest South	2	434	436	11
Resort	9	417	426	10
Residential	151	856	1,007	25
High Density Urban	110	110	220	5
Total subwatershed	282	3,808	4,090	100

Note: Forest North and Forest South refer to the aspect, not to whether the area is located to the north or south of the lake
Source: Modified from Hydmet, Inc. 2004

Geology. The San Bernardino Mountains are part of the Transverse Range Geomorphic Province of California. The geology of the Big Bear Lake watershed is composed principally of three distinct rock groups: carboniferous and pre-carboniferous sedimentary rocks; volcanic and metamorphic rocks; and Cenozoic sedimentary deposits (Owen and Associates 1977, III-33) (Figure 1-9).

These geologic formations can be divided into two categories: water-bearing and non-water bearing. The Quarternary unconsolidated deposits (e.g., Recent Alluvium (Qa), Older Alluvium (Qoa) and Older Alluvial Fan Deposits (Oof)) are considered water-bearing and comprise the largest percentage of the groundwater reservoir in the Big Bear Lake watershed. The recent alluvium is primarily present in stream bottoms and flood plains at lower elevations. This alluvium consists of gravel and sand and is from other rock units in the tributary drainage basin. The Paleozoic Furnace limestone has a higher water yielding potential than the other basement complex rocks due to the solution channels within the limestone bodies (Crandall and Associates 1978, 2-4).

The non-bearing rock formations may contain limited amounts of water in fractures or joints, but do not absorb, transmit, or yield water readily. These types of rock formations consist of igneous and metamorphic rocks that range in composition from quartz monzonite to quartz diorite, biotite diorite gneiss and quartzite (Crandall and Associates 1978, 4).

The physical condition of the crystalline, nonwater-bearing rocks ranges from completely crushed rock to massive, moderately jointed rock. Deep weathering is evident in some areas, and in some of the creek bottoms, the rock outcrops are intact and more massive (Crandall and Associates 1978, 5).

In the Big Bear Lake watershed, production of sediment includes weathering processes and transport likely includes mass wasting and watershed erosion. These processes will be evaluated in greater detail during 2005 and 2006 as part of a Proposition 13 grant.

Weathering processes. The primary source of sediment delivered to rivers in California occurs by chemical physical weathering of minerals and breakdown of parent material (Mount 1995, 102). Weathering rates are controlled by temperature, the quantity of water and its movement, acidity and the properties of minerals (Leopold, Wolman and Miller 1995, 116).

Mass wasting processes. Because of the steep slopes within the Big Bear Lake watershed, mass wasting processes are likely a dominant form of erosion. Mass wasting is the movement of soil, rock and organic debris downslope by gravity and consists of landslides, rockfalls, debris avalanches, debris flows, slumps, soil creeps, and others (Beschta 1996, 123).

Watershed erosion. Watershed erosion includes both surface and channel erosional processes. Surface erosional processes consist of rainsplash, sheetwash, and gully and rill erosion. Channel erosional processes include both streambed and streambank erosion.

Rainsplash erosion occurs when raindrops hit the surface and dislodge and transport soil particles downhill. Rainfall intensity, slope steepness, amount of vegetative cover, and the resistance of the soil to erosion all factor into the amount of erosion that occurs due to rain. Construction sites, road cuts and recently burned areas are locations that are affected by this type of erosion (Mount 1995, 106-107).

Overland flow occurs only when the infiltration capacity of the land surface is exceeded and the depression storage is filled. This flow is also called Horton overland flow, or sheetwash, and causes the highest rates of hillslope erosion. Factors that are important in controlling the amount of sediment transported by overland flow are the type and amount of vegetative cover, BMPs implemented to control erosion, steepness of the slope, resistance of the soil to erosion, and the distance that flow travels across a slope (Mount 1995, 107-108). Changes in land use, such as conversion of forested areas to urban areas, can alter flow regimes and surface runoff patterns. As an area becomes more impervious, changes in the hydrograph result in an increase of discharge over a shorter time period because the runoff has a reduced ability to infiltrate the soil and has less natural resistance to flow. This alters overland runoff, causing erosion and the transport of sediment, especially the finer-material such as silts and clays, and increasing channel erosion (Guy 1970).

The last type of erosion is from formation of rills and gullies. Rills are tiny incisions or channels formed by concentrating flows on uneven surfaces. Gullies are formed by rills that continue to incise with each significant overland flow event, and are one or more feet deep. Rills and gullies usually contribute only a minor amount of sediment to the overall sediment budget, except in the case of rivers that are adjacent to construction sites and road cuts that are particularly susceptible to rill and gully erosion and can then be important to the overall sediment budget (Mount 1995, 108).

Stream channels continuously adjust in response to one or more changes in eight variables (channel width, depth, slope, discharge, velocity, hydraulic roughness, sediment load and sediment size) in order to attain equilibrium (Leopold, Wolman and Miller 1995, 268). Fine sediment particles are suspended in the water column and usually move down the channel with the flow. Coarser-grained particles usually only move short-distances or roll and bounce along the stream bottom. Rill and gully flow carry the finer-material as well as any coarser material that is eroded from the banks and bed of the channel. Due to these differences in the transportation of differently-sized sediment particles within streams, variations in sediment concentration at a given cross-section are expected (Guy 1970).

Soils. A soil survey of the San Bernardino National Forest Area was prepared from fieldwork conducted in 1974-1979 (Cohn and Retelas n.d., ii). This survey is an Order 3 survey, meaning that every delineation of each different map unit was not verified in the field and the exact location of each soil type was not delineated. Instead, a number of soil map units were identified, each of which consists of a group of soils with similar landforms, parent rock material, and similar geographic areas and is named after the major soils or miscellaneous areas occurring in the unit (Cohn and Retelas n.d., 8). Field verification of the survey is needed prior to any type of project planning. Other soils data available in GIS format include the STATSGO[3] data used in the watershed model (see Section 4.0- Source Assessment,) and newer SSURGO[4] data for the San Bernardino National Forest Area.

Six soil map units are identified in the Big Bear Lake watershed, including (30%) Morical, very deep-Hecker families complex; (30%) Pacifico-Wapi families complex; (19%) Pacifico-Preston families complex; (8%) Merkel-Switchback families complex; (13%) Lithic Xerorthents, calcareous-Lizzant family association; and (0.4%) Morical-Wind River families complex[5] (Figure 1-10). These units are found on moderate (2-30%) to steep (30-50%) slopes. The soils are generally somewhat excessively drained to well drained. The matrix of these soils is sandy loam and loamy sand. Soil families are made up of soils that have similar profiles[6]. Each soil map unit consists of a description of soil features such as slope gradient, slope stability, maximum erosion hazard, soil depth, and permeability, which aids in the determination of which soils are suitable for specific uses (Cohn and Retelas n.d., 8,17-21). Shown in Table 1-4 are some selected properties of soil units found in the Big Bear Lake watershed.

[3] STATSGO is the State Soil Geographic data base with data at a scale of 1:250,000, prepared by the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS).
[4] SSURGO is the Soil Survey Geographic data base with data at a scale of 1:24,000, also prepared by the NRCS.
[5] Note that the percentages were obtained from GIS analysis of the soils map. The percentages are based on land area only and do not include the lake itself. More discrete classes of soils are available; however, this analysis used the soils map and associated information that was prepared for the HSPF modeling effort (see Section 4.0). In the future, a more detailed soils map can be prepared.
[6] A soil profile is the vertical arrangement of layers of soil (i.e., soil horizons) down to the bedrock.

Table 1-4. Selected properties of soil map units found in the Big Bear Lake watershed

Soil Map Unit Name	Soil Map Unit Symbol	Depth (in.)	Slope %	Hydrologic Soil Group	Erosion Hazard
Morical, very deep-Hecker complex	BoD	36 to 60	2 to 15	B	Moderate
Pacifico-Wapi complex	DaE	10 to 20	15 to 30	C	High
Pacifico-Preston complex	DdDE	15 to 28	2 to 30	C-B	Moderate
Merkel-Switchback complex	FbE	18 to 30	15 to 30	B	Moderate
Lithic Xerorthents, calcareous rock outcrop, Lizzant complex	FrF	24 to 46	30 to 50	C-B	High
Morical-Wind River complex	MbF	20 to 50	30 to 50	B	High

Source: Cohn and Retelas n.d., 28,37,42,57,62,76
Hydrologic soil groups are used to estimate runoff from precipitation. Soils that aren't protected by vegetation are assigned to one of four groups, increasing in runoff potential from A to D. A =low runoff potential; B = moderately low runoff potential; C = moderately high runoff potential; D = high runoff potential. Maximum erosion hazard appraises relative risk of accelerated sheet and rill erosion; the system does not rate gully erosion, dry ravel[7], wind erosion, or mass wasting. Erosion hazard assessment is based on little or no vegetative cover and on the long-term average occurrence of 2-year, 6-hour storm events. Erosion hazards are greater when storm frequency, intensity and/or duration exceed long-term average occurrence. Very high and high erosion hazard: accelerated erosion will occur in most years. Moderate erosion hazard: accelerated erosion likely to occur in most years.

The most likely areas for high erosion potential based on soils and slope steepness are indicated in Figure 1-11.

[7] Unconsolidated material consisting of rock fragments, finer grained earth material, and organic matter deposited on and at the base of steep slopes by direct gravitational action (Cohn and Retelas n.d., 152).

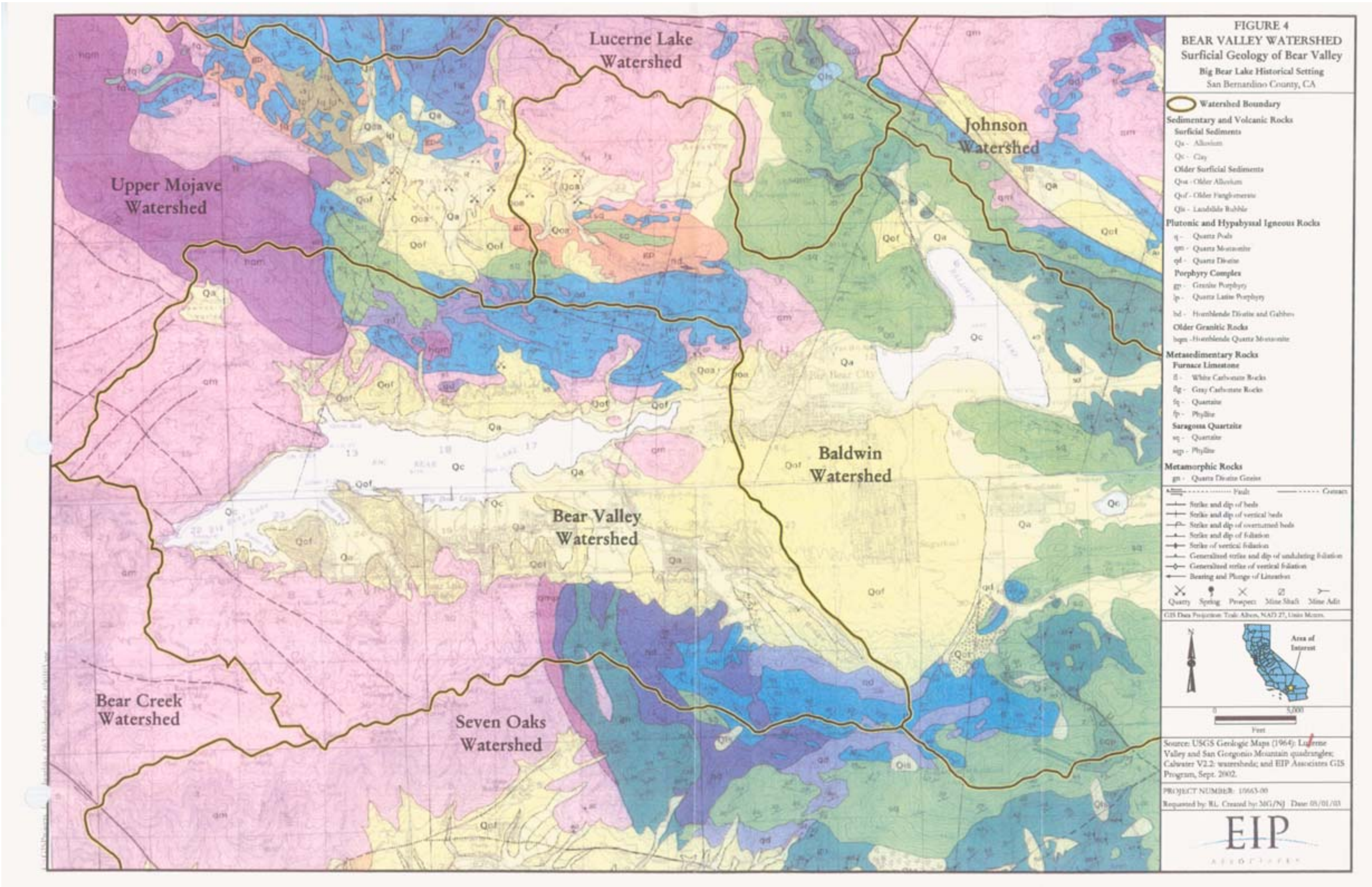


FIGURE 1-9. SURFICIAL GEOLOGY OF THE BIG BEAR LAKE WATERSHED (Source: Leidy 2003)

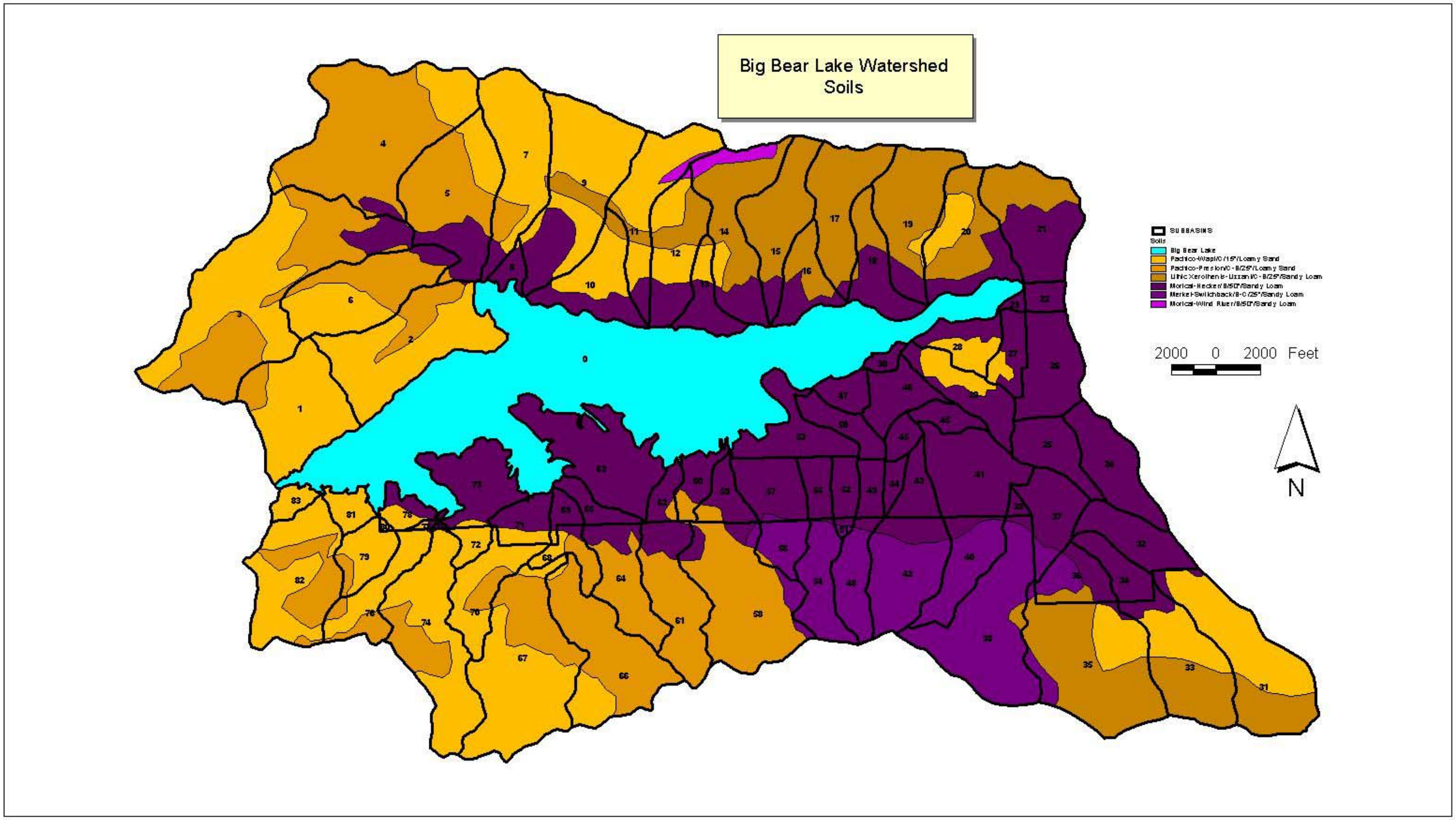
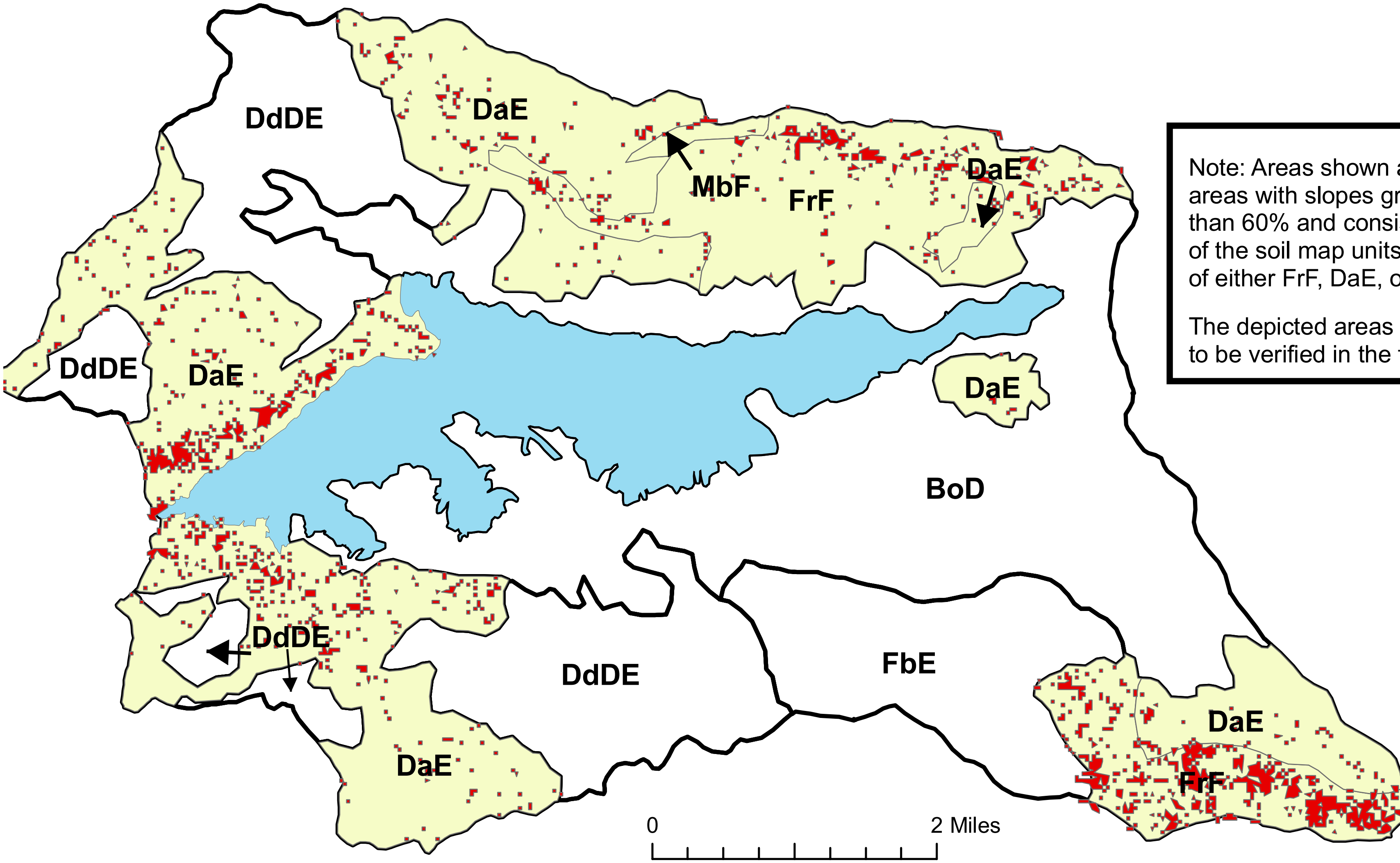


FIGURE 1-10. SOILS MAP OF THE BIG BEAR LAKE WATERSHED (Source: Hydmet, Inc. 2003)



Note: Areas shown are those areas with slopes greater than 60% and consisting of the soil map units of either FrF, DaE, or MbF.

The depicted areas need to be verified in the field.

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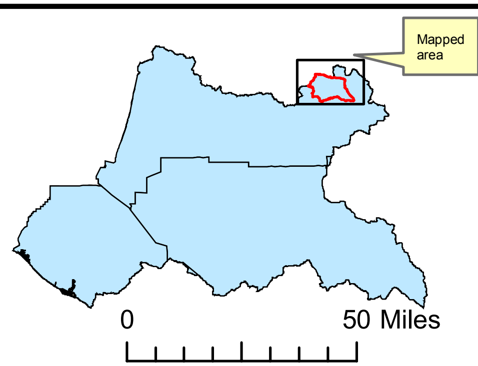
Data Sources:
Soil data: Hydmet, Inc., 2003
TIN used to calculate slope:
San Bernardino County, 2004



N

Map Features

Slopes > 60%

Soil map unit

Figure 1-11.
Areas within the Big Bear Lake watershed most susceptible to erosion

D:GISDATA/BBL/BBL_sed1.mxd

Map contact: Heather Boyd, CA Regional Water Quality Control Board, Santa Ana Region, July 2005

Fish and Wildlife. There are two fisheries in Big Bear Lake, a warm water fishery consisting of centrarchids (largemouth bass, bluegill and pumpkinseed) and channel catfish, and a cold water fishery, with frequent stocking of rainbow trout. In addition, there are large populations of carp present in the lake. The three centrarchids, members of the Sunfish family (Family taxon Centrarchidae), spawn at different water temperatures. The largemouth bass spawns in the early spring when water temperatures are at 14-16º C, the bluegill spawns when water temperatures are at about 18-21º C, and the pumpkinseed spawns when water temperatures are at about 20º C. These fish have different dietary and habitat preferences as well. The pumpkinseed prefer damselfly naiads and gastropods and prefer the dense macrophyte beds. The bluegill's diet consists of zooplankton, damselfly naiads, and chironomids and they prefer the fringe of the weed beds. The largemouth bass' diet consists of chironomids, crayfish and fish. The bass also prefer the fringe of the weed beds but select larger prey than the bluegill (Siegfried et al. 1978, 49-50). Half-pound Rainbow trout from the Mojave Fish Hatchery are stocked in Big Bear Lake twice a month from April to November, with a 36,000 lb allotment per calendar year. One hundred fifty thousand subcatchables are also stocked per year. These smaller, 6-inch rainbow trout are an Eagle Lake trout strain (Uplinger 2000). According to the Big Bear Municipal Water District (2002), there are 9 species of fish in the lake (Largemouth bass, smallmouth bass, silver salmon, bluegill, pumpkinseed, crappie, catfish, carp and rainbow trout). Because of these habitat and dietary differences, it is important that the aquatic plant community in the lake consist of a variety of species and that no one species forms a monoculture, as Eurasian watermilfoil has essentially done in Big Bear Lake. A diverse aquatic plant community is necessary to support the diversity of fish and other wildlife species. The development of a monoculture threatens the diversity of the biota.

Rare/Threatened/Endangered Species. Bald eagles winter at Big Bear Lake and adjacent Baldwin Lake. In 1998, there were approximately 15 to 28 bald eagles. The eagles perch in trees within wooded areas along the southern lakeshore, around Metcalf Bay and Eagle Point, and along the eastern shore of the lake. They also forage on fish within Big Bear Lake. Any outdoor activity that could disturb the eagles should be restricted from December 1 through April 1 (City of Big Bear Lake 1999, ER-5, ER-6).